

# Is opposition to GM crops science or politics?

An investigation into the arguments that GM crops pose a particular threat to the environment • by Anthony J. Trewavas & Christopher J. Leaver

Question 101: 'Lord Melchett, in relation to genetic modification, what do you object to and why?'

Lord Melchett, Head of Greenpeace, UK: 'My Lord Chairman, the fundamental objection is that there are unreliable and unpredictable risks.'

Question 105: 'How far are you prepared to carry your objections to these developments?'

Lord Melchett: 'I am happy to answer for Greenpeace [...] Greenpeace opposes all releases to the environment of genetically modified organisms.'

Question 107: 'Your opposition to the release of GMOs, that is an absolute and definite opposition? It is not one that is dependent on further scientific research or improved procedures being developed or any satisfaction you might get with regard to the safety or otherwise in future?'

Lord Melchett: 'It is a permanent and definite and complete opposition based on a view that there will always be major uncertainties. It is the nature of the technology, indeed it is the nature of science, that there will not be any absolute proof. No scientist would sit before your Lordships and claim that if they were a scientist at all.'

House of Lords Select Committee on European Communities. 2nd Report: EC Regulation of Genetic Modification in Agriculture.

## Agriculture past and future

During the last century, the world population tripled to 6 billion. While food production has increased accordingly, some 800 million people, primarily in the developing world, still do not have access to sufficient food. Forty thousand people die every day from malnutrition, over half being children under the age of 5. In addition to lack of food, deficiencies in micronutrients,

such as vitamins and iron, leading to illness and death are widespread.

The World Health Organization estimates that the earth's population will reach 9 billion by 2050. The vast majority of this increase will occur in the developing countries of South East Asia and sub-Saharan Africa, and it is estimated that >50% of this population will live in urban areas. To meet this challenge over the next 50 years, we must double-to-triple the production of food on, essentially, the same area of land in the face of decreasing water supplies and with respect to the environment. This will be made more difficult by the consequences of global warming, such as increased climatic variability, changing patterns of rainfall and new pests and diseases. At the same

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time there must be a cessation of wilderness erosion to protect biodiversity and maintain ecosystems.

Since the 1970s, the world has also seen a revolution in our understanding of how organisms function at the molecular, biochemical and physiological level. An integral part of this revolution has been the development of technologies that allow the transfer of genes from one species to another. Many scientists believe that the application of biotechnology to agriculture—together with plant breeding and improved agricultural practice—may provide solutions to some of the challenges outlined above. We do not claim that GM crops will feed the world or eliminate poverty. But in order to both satisfy the environmental concerns that come with modern agriculture and

global warming, while still feeding the increasing world population in a sustainable and nutritious manner, we must assume responsibility for fully evaluating this technology for future generations.

As with many new technologies, people are keen to embrace the benefits but reluctant to accept potential risks. The manner of introduction of GM crops onto the market has led to widespread loss of public confidence, which has been exploited by non-representative groups and activists for their own political ends. Some hypothesised threats of GM crops to the environment are elevated as being more important than the security of mankind. And the future that the critics offer is bleak: hard-won knowledge is rejected in favour of ideology. They require an absolute safety guarantee for GM crops, but such a warranty cannot be given since we can never know everything about anything. Thus, a standard of absolute certainty will effectively stop the attainment of the benefits of this or any other technology. As well as the ethical obligation to do no harm there is an obligation to strive for good in an imperfect world.

Many of these concerns were submitted to the US Environmental Protection Agency in 1997. In their response, the EPA thoroughly addressed each of the questions raised (EPA, 2000). Our own response is unfortunately limited by space. However, we wish to address the most important criticisms that opponents of GM crops make to try and block their introduction.

## Can GM crops be recalled?

In natural ecosystems, plant numbers are limited by specific forms of allelopathy and predation just as animals are controlled by predators. When constraints are lifted in a new environment, easy spread may occur

for a time. A few introduced animals, such as rabbit, mink and Nile Perch, as well as plants—Japanese Knotweed and *Rhododendron ponticum* in the UK—have indeed become a nuisance and are difficult to eradicate. But the nuisance plants are neither GM organisms nor domesticated crops. It is interesting to note that the UK native flora is generally considered to number ~1600 species but that there are ~3500 alien species growing in the UK, the majority introduced by horticulture.

Furthermore, the genetic makeup of GM crops makes it unlikely that they could become 'superweeds'. At least twelve genetic traits are required to produce a successful weed (Chrispeels and Sadava, 1994), while it is estimated that domesticated crops contain only six of them. Consequently, such crops will disappear quickly in the wild because existing weeds easily outcompete them. A recent study (Crawley *et al.*, 2001) placed GM crops—all of those available at the time the study was initiated—along with comparable conventional varieties, into 12 natural habitats. The fate of GM and conventional oilseed rape, maize, sugar beet and potato were then monitored over a period of 10 years. In no case did transgenic plants persist longer than their conventional counterparts. Every crop species, GM and conventional, died off within three years, except for one conventional potato. These data suggest that arable crops do not survive long outside cultivation, and their persistence was not affected by the introduction of insect resistance and herbicide tolerance traits. On this basis any current GM crop can be recalled or can be killed by herbicides *in extremis*.

## Is GM entirely new or an extension of current plant breeding?

The genes introduced through GM are not qualitatively different from those genes introduced by conventional breeding from exotic sources or from novel genes produced through mutation. Weed populations, from which crops were domesticated, are a sea of natural mutants; without such variation, the

species would never survive disease, predation and the constant competition.



However, opponents of GM technology try to perpetuate the misunderstanding that transgenic crops are unlike the results of conventional breeding, that the process by which they are produced is uncontrolled and that the associated risks are unique. On the contrary, the WHO, The Royal Society, the US National Research Council and the Organisation for Economic Co-operation and Development have consistently concluded that the risks associated with GM crops are not unique to these products and hence, that standard risk assessment approaches are appropriate. In fact, the processes used to produce GM crops are, if anything, more precise and less likely to produce

chromosomes of maize have been recovered as single additions to individual haploid oat plants, for example (Kynast *et al.*, 2001). Cereals and wild grasses have frequently been crossed in order to incorporate disease resistance genes. Triticale, grown on 1 million ha, is a lucky cross between wheat and rye. But such breeding requires decades of repeated backcrossing to eliminate unwanted deleterious traits. So why wait such a long time if GM can achieve the same goal in a few years?

Admittedly, GM inserts new genes into random positions of the plant's genome. But any new cross, whether created through GM or conventional breeding, introduces changes randomly (e.g. transposon movement) and can exhibit instability, pleiotropic effects and unwanted side characteristics resulting from genomic rearrangements and random movements of DNA. Conventionally bred variants of potato, squash and celery had to be withdrawn after they were subsequently found to be toxic under particular conditions (Ames and Gold, 1999; USDA, 2000).

However, we accept the necessity for stringent testing for all new GM crops to eliminate such problems. Ecological risk assessments for GM crops, as for any product, are performed on a case-by-case basis. All risk assessments involve an initial identification and characterisation of possible threats. In cases where problems are identified, management

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unanticipated effects. The parental line is available for comparison and only few genes are introduced into an established genetic background instead of mixing whole genome complements through sexual crossing (Conner and Jacobs, 1999). Conventional crop breeding, by crossing with adventitiously detected crop mutants (natural GM), radiation or chemically induced mutagenesis, has produced many unnatural combinations that would never occur in the wild. All ten

strategies are developed to protect the environment. We do not think that risk assessment techniques are inappropriate for GM crops, nor is this the view of regulators or scientific authorities. Furthermore, crops produced by conventional breeding require no such safety assessment.

## Gene flow concerns

Gene flow is not something that originated with GM, but has been going

on for millennia since man started cultivating crops. We would like to use herbicide (atrazine)-tolerant rape as an example to clarify whether gene flow could give rise to herbicide-resistant weed varieties. It was developed from naturally arising resistant mutants generated by conventional breeding and has been available commercially for 20 years without reported weed problems. The yields are 20% lower than with non-resistant varieties but the advantages of weed control without ploughing ('zero tillage')—particularly on sloping farmland and the reduced damage to soil invertebrates offset the lower yield. So if the same trait can be introduced by GM without causing yield loss this would provide significant benefits.

There are natural barriers to gene flow. Plant breeders have known for some time that a separation of 100 m maintains 99.9% genetic purity of two rape stocks. Rape and weedy relatives produce at least

rapidly disappear once the crop is removed from the field. So far, no new and damaging weeds have emerged despite the conventional production of pest, virus and disease-resistant rape and beet.

## *Bt* corn, Monarch butterflies and lacewings

Criticism often focuses on a small set of laboratory studies that typically test non-target species under unrealistic conditions or focus on hazard alone without considering the level of exposure that will occur under natural conditions. The critics also fail to acknowledge scientific literature that draws opposite conclusions.

The *Bt* protein from *Bacillus thuringiensis* used in insect-resistant crops is one of a family of over 140 proteins that specifically kills moth and butterfly caterpillars and some beetle larvae when consumed. The corn borer is a moth larva causing severe damage to crops and requires substantive pesticide treatments for control. Expression of the *Bt* protein in corn substantially reduces otherwise-necessary pesticide applications, thus helping to mitigate unwanted damage to non-target insects. The migratory Monarch butterfly lives on milkweed plants in the USA that can be found growing at the margins of corn-fields as well as elsewhere. The initial study on the impact of *Bt* maize pollen on larvae of the Monarch butterfly ( Losey *et al.*, 1999) showed that heavy sprinkling of pollen on milkweed leaves in the laboratory—the amount used was not quantified—damaged the Monarch butterfly larvae that ate the leaves. This was not an unexpected result—*Bt* protein kills butterfly and moth larvae—but it caused considerable controversy. However, subsequent studies under natural field conditions demonstrated that both larvae of Monarch butterflies and other non-target *Lepidopterans* will not be exposed to sufficient amounts of pollen that could cause adverse impacts (Sears *et al.*, 2000; Trewavas and Leaver, 2000; Hellmich and Siegfried, 2001). We now know that the original 'Losey' study was a worst-case scenario, just as an airline crash is the worst-case scenario for flying. It was therefore no surprise that Monarch populations increased by 30% throughout 1999 ([www.monarchwatch.org](http://www.monarchwatch.org)) when

30% of all corn grown in the USA was *Bt* corn. Reduced pesticide use was thought responsible. Later, it was found that shedding of corn pollen is out of step with Monarch larval development and that pollen concentration declined rapidly beyond the cultivated field—many milkweeds grow outside the farm environment. But the result pointed to the necessity for detailed environmental testing of GM crops.

A similar controversy ensued when Hilbeck *et al.* (1998) reported that the breeding capacity and viability of predatory lacewings was reduced when they were fed on caterpillars feeding on *Bt* levels >10-fold higher than those in any GM maize tissues. Again, a worst case scenario. When the lacewing were given a choice, they showed an almost unanimous disregard for the dying caterpillars fed on *Bt* leaves (Schuler *et al.*, 1999).

Crecchio and Stotzky (1998) have shown that *Bt* proteins can persist in soil under certain conditions, which might risk exposure of some non-target organisms. However, other studies have shown that most of the *Bt* protein found in *Bt* maize, cotton or potatoes rapidly breaks down in soil and that non-target species present in soil are not susceptible to *Bt* proteins (EPA, 2000, 2001). Estimating real risk requires demonstrating both hazard and exposure under natural conditions.

GM corn, cotton and soybean have been in commercial use for over five years now, and millions of hectares have been grown without any field reports of adverse ecological impacts. Substantial environmental benefits have been established for some of these products, such as *Bt* cotton, because of the resulting reduction in the use of chemical insecticides (Gianessi and Carpenter, 1999, 2001). Over that same period, large-scale, field-based studies in the USA, China and Europe have been completed that have consistently found no negative effects from *Bt* cotton or maize (for example, Pilcher *et al.*, 1997; Lozzia, 1999; Xia *et al.*, 1999). Indeed, populations of predatory arthropods that help to control secondary pests like aphids are found to be consistently higher in *Bt* cotton fields than in sprayed fields of conventional cotton.

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a 5000-fold excess of pollen over egg cells. Competing pollen from elsewhere has thus to contend with a much larger volume of pollen to be found in close proximity to the stigma. Pollen spread falls off rapidly with distance from the field, although very low levels of pollen may be detected at distances of kilometres. Thus, it is essential to distinguish between pollen distribution and actual pollination. Activist groups have generated much confusion by failing to distinguish adequately between these two factors.

Oilseed rape has four to five weedy relatives in the UK, but genes will only be transferred if wild relatives are sexually compatible and flower at the same time. Estimates put the chance that rape (*Brassica napus*) will form hybrids with its nearest relative (*Brassica rapa*) at 1 in 10 000 (Scott and Wilkinson, 1998). These hybrids will only persist if the herbicide-resistance gene gives them a selective advantage. Outside the agricultural environment these genes are considered to be of no advantage, and thus, such hybrids will



## Will herbicide-resistant crops lead to an increase in herbicide use?

Published studies on herbicide use for Roundup Ready (RR) soybeans have been mixed, with some studies reporting no change and other studies reporting a small reduction in overall herbicide use. A thorough analysis in the USA reported a small but significant decrease in herbicide use as a result of soybean planting in 1997 (USDA, 2000). Another analysis reported that US soybean growers replaced 7.2 million pounds of other herbicides with 5.4 million pounds of Roundup (Heimlich *et al.*, 2000). Glyphosate, the active ingredient in Roundup, has an average half-life of 47 days, compared with 60–90 days for the

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herbicides replaced. Additionally, the herbicides replaced are 3.4–16.8 times more toxic than glyphosate, according to the EPA reference dose for humans. Thus, the substitution resulted in the replacement of herbicides that are at least three times more toxic and that persist nearly twice as long (Heimlich *et al.*, 2000). Furthermore, a recent study by Kline and Co., a New Jersey-based consulting firm, indicates that herbicide-tolerant crops will contribute to an annual reduction of 45 million pounds (~20 000 tonnes) in herbicide active ingredient by 2009 (Kline and Co., 2001). In Canada, a recent study reported that herbicide-tolerant canola (oilseed rape) eliminated the use of >6000 tonnes of herbicide in the 2000 growing season (Canola Council of Canada, 2001).

The secondary consequences of reduced pesticide use include overall energy savings and waste reduction through lower production, packaging, transportation and application of pesticides. Taken together with increased yields, this represents an opportunity for greater sustainability and land conservation.

## Conclusions

The information available to address the ecological impacts of GM crops

reinforces the findings of earlier risk assessments: that GM crops often produce clear environmental and ecological benefits compared with some of the technologies that they are replacing. Indeed, many of the criticisms raised of GM crops are more a reflection of concerns about the changing nature of agriculture rather than specific fears related to GM crops (Beringer, 2000).

We recognise that there are real and legitimate concerns over modern agricultural practice and we believe that the application of the best science, with appropriate regulations, will lead to the development of GM crops that have the potential to solve the problems of sustainable food production. Claims by critics, however, should be considered in the context of demonstrated safety and benefits rather than unsubstantiated risks. Misinterpretations and misunderstandings of the regulatory process and of GM crops must not be allowed to block a technology that is already delivering real benefits today and promises important, sustainable benefits in the future.

The world community has set in place proper regulatory systems to test GM crops and monitor their subsequent fate. The way forward is always to act on the best available knowledge. But to act instead on exaggerated and unsubstantiated speculations that come from a poor understanding of biology, or perhaps solely on ideology, is much more certain of disaster. Who then would pay for the lives lost and for the ecological and economic damage? It is unlikely to be those who agitated in the first place.

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## Foot-and-mouth disease in Europe

FMD is economically the most important disease of farm animals. Its re-emergence in Europe is likely to have consequences that go beyond severe alterations of livestock production and trade • by *Francisco Sobrino & Esteban Domingo*

On February 21, 2001, the United Kingdom officially declared an outbreak of foot-and-mouth disease (FMD) in England. Since then, the disease has spread like a bush fire among farm animals—mainly sheep and cattle—reaching a total of 1461 confirmed outbreaks by April 20, and, in March, appeared in continental Europe with one confirmed outbreak in The Netherlands. To prevent further spread of FMD—so far, a hopeless effort—British officials have slaughtered and destroyed more than 2 million animals, such a massive undertaking that the British army had to be ordered to help. (Updated information can be found at the Office International des Epizooties: [www.oie.int](http://www.oie.int)).

This is the first major FMD epizootic in the UK since 1968, and it represents a monumental set-back for the non-vaccination policy that the EU implemented in 1991. Losses were initially estimated to be 6 billion Euros, but this is likely to be an underestimate. The FMD outbreak, added to the BSE crisis, must call into question whether the existing human and animal health policies in the EU are still adequate in the context of a highly competitive and a global economy.

Foot-and-mouth disease virus (FMDV), a representative of the aphthovirus genus of the *Picornaviridae* family, causes the disease that is ravaging the UK. The term aphthovirus derives from the Greek 'aphtha', which refers to the vesicles found in the mouth and feet of affected animals. It was first identified in 1898 by Loeffler and Frosch (Bachrach, 1968). Earlier, Fracastorius described (in a book published in 1546), a disease of cattle, which occurred in Venice in 1514, and which, most likely, was FMD. The disease was endemic in Europe from the seventeenth until the nineteenth century, and became more frequent in the first half of the twentieth century, as a result of more intensive cattle breeding and increased traffic of susceptible animals (Bachrach, 1968; Pereira, 1981). With the exception of New Zealand, FMD has occurred at one time or another in most locations of the world. An important epizootic in Mexico from 1946 until 1953 was prevented from spreading to the United States—disease-free since 1929—through a huge surveillance programme.

The 2001 European epizootic is associated with the unprecedented entry of serotype O PanAsia FMDV from Asia (Knowles *et*

*al.*, 2001). The PanAsia FMDVs form a distinct phylogenetic cluster amid other type O viruses that have been circulating mainly in Asia and the Middle East. The virus that caused the current outbreak was first detected in 1990 in India and rapidly spread both eastward and westward. In Europe, it has found a fully susceptible animal population to thrive on.

FMDV particles are spherical, with icosahedral symmetry and devoid of a lipid envelope (Acharya *et al.*, 1989). The capsid encloses a single-stranded RNA molecule of approximately 8500 nucleotides. After translation, proteins are processed from a single polyprotein precursor. FMDV enters the animal host through the respiratory tract or through skin abrasions, and initiates a poorly understood replication cycle with an incubation period of generally 1–8 days. A viremic phase (virus in the blood) precedes the development of the characteristic vesicles, which makes control of the virus more difficult. It has been estimated that infected cattle may harbour up to  $10^{12}$  infectious units. Large amounts of virus are found in the lesions of infected animals as well as in their secretions and excretions, particularly from pigs.